Discussion before the Wireless Section, 1st February, 1928.

Mr. P. K. Turner: This paper gives a clear statement of policy which affects us all very closely, and I should like to express my own appreciation of that policy. There are, however, some points on which I am inclined to diverge just a little, and the first of such points is one that is referred to several times in the paper, and notably where the author says " It is important to study the problem in terms of existing reception technique." That idea is present throughout the paper, and is developed to its fullest extent in the discussion on service

areas. I cannot help thinking that the author is rather pessimistic in the view he takes of the possibilities of the average set of to-day, and possibly of the average set of to-morrow. The British Broadcasting Corporation are very anxious to give such a full field strength that reception, even with the most rudimentary apparatus, shall still be certain, and I am wondering whether it is not perhaps a mistake to " spoon-feed " the foolish quite so freely, and whether it would not be justifiable to economize to a certain extent in the matter of field strength and perhaps give a stimulus to the improvement of receiving apparatus. We all know that we can habitually receive quite comfortably and regularly outside the " C " service area. I quite agree that there are persons who make and use receivers who cannot get such reception, but are they worthy of such a great amount of consideration when unskilled persons with reasonably good apparatus can be well served with less field strength? One point in regard to which I should like to express my very full agreement with the author is where he speaks of the necessary frequency gamut of the receiver, and says that the receiver should extend its powers from 30 to 10 000 cycles or thereabouts. A point which is perhaps not fully realized is that if one is working with a loud-speaker which is proved to fall off in efficiency very rapidly below, for example, 50 cycles, none the less its performance is perceptibly improved when the range of the associated receiver is extended from 50 cycles down to 30; in other words, the performance is improved although the additional frequencies are beyond its range. The point is one which I have already raised and attempted to explain to a certain extent, but I should like to hear the views of others on it. In discussing receivers, the author refers to two fundamentally distinct uses of filter circuits, one of which is the band-stop filter—in its most rudimentary form of a closed circuit in series with the aerial and tuned to the frequency of the unwanted transmission. He appears to approve of that as a simple way out when there is strong interference from one particular station. My experience is that it is not nearly so simple as it appears, and I think that further information on the handling of such circuits is necessary. The other use of the filter circuit which he mentions is the use of a band-pass filter as a means of achieving selectivity. I have done a certain amount of tentative work on tuning with band filters in which the width of pass band is definitely assigned, and the pass band is shifted up and down the broadcast band in the same way as with any ordinary set. In other words, instead of having three or four high-frequency valves with intermediate tuned coupling, one locates the whole of the tuning arrangements in one place and puts them in the form of a band-pass filter. Those experiments are only tentative, but they appear to be full of promise, and there are many reasons why the idea should have considerable advantages if carried out properly. Further on in the paper the author refers favourably to experiences with land lines, and I cannot help feeling that his pessimism with regard to the performance of receivers is to some extent balanced by an undue optimism with regard to land lines. He says " Experience has proved that it is perfectly feasible to rely upon the use of such connection, and that no serious loss of quality in the transmission need be feared if proper precautions are taken," which, of course, is undeniable; but I have known occasions when the " proper precautions " had evidently not been taken. No one can deny the extraordinary difficulty, from the Post Office point of view, of transmitting a band of 30 to 10 000 cycles over long Post Office lines. Is the author definitely of opinion that it is practicable habitually to transmit that frequency band? In discussing the design of broadcasting transmitters, the author says " It should be possible to modulate the high-frequency aerial currents to the fullest possible extent without introducing distortion." I should like to say, as a designer of receiving sets, that I object strongly to very full modulation, because it increases the difficulty of distortionless rectification to a very considerable extent. Many types of simple detector which will rectify a lightly modulated signal will not deal with one which is very deeply modulated, and though I have protested against too much consideration being shown to out-of-date receiving sets I should like some consideration to be extended to the designers of receiving sets in this respect. On the question of " control," I should like to put forward my personal view that control can be very easily overdone.

Mr. A. G. L. Mason: Embodying so concisely the fundamental principles underlying the operation of broadcasting systems, and voicing the considered opinion of the British Broadcasting Corporation on many of the debated problems of design, this paper is certain to carry weight with those responsible for the conduct of broadcasting services in other countries. It is therefore interesting to note that after an investigation of both high- and low-power modulation, the author has pronounced himself in favour of the latter system, the advantages of which he has so clearly explained. The company with which I am associated has, since the very early days of broadcasting, employed low-power modulation for all transmitters of 1 kW or greater output. In 1925 we installed a 1-kW equipment of this type at the Birmingham station of the British Broadcasting Corporation, and I am sure the author will agree that the experience gained in handling this set did much to draw their attention to the merits of the system. I think, however, that the author does an injustice to low-power modulation when he suggests that it renders the equipment more liable to trouble from valve " flash over " than the other system. This deduction is apparently drawn from the fact that such " flash over " occurs more frequently on the 5GB transmitter, which uses low-power modulation, than on 5XX, where high-power modulation is employed. It is suggested that the comparative immunity of the latter station is due to the action of the high-power modulation choke in opposing any sudden current-rise, but it is difficult to accept this explanation inasmuch as with low-power modulation there are also highly inductive chokes in the high-tension smoothing circuit which will have a precisely similar effect. Although the author is apparently unconvinced, I personally am fairly sure that the real cause of the " flash over " trouble at 5GB is the use of a d.c. machine for high-tension supply, in place of the rectifier employed at 5XX. In the course of considerable experience with

low-power modulation equipments of all powers up to 30 kW output and operating with anode voltages up to 12 000 volts, my company has had no valves damaged by "flash over." In every case all of the voltages higher than 4 000 volts have been obtained from rectifiers, and I think this explains the freedom from trouble. With regard to the suggestion made in the paper that owing to the charged smoothing condensers a rectifier and a d.c. machine differ little in the amount of energy they are able to release into a fault, a brief calculation shows that the total heat energy stored in a 20 μF condenser charged to 10 000 volts is approximately 250 gramme-calories, an amount which is evidently insufficient to cause any material damage. The study of this flash-over phenomenon is at present engaging the attention of all who have to do with high-power valve transmitters. The occurrence, or at least the effect, of the phenomenon seems to be determined largely by the number of valves connected in parallel and by the nature of the high-tension supply. It would therefore be of great interest if the author would state whether at 5GB the low-power amplifiers which drive the final amplifier are fed from the same high-tension source as the latter, and, if so, whether flash-over has ever occurred on these smaller amplifiers. It would also be interesting to know what proportion of the rather numerous breakdowns at 5GB has in fact been due to valves flashing over. The comparison made between the operating costs for a high-tension machine and a rectifier system is, I think, rather unfair to the latter. An efficiency of 60 per cent is rather a low figure for a good rectifier, as with the double 3-phase arrangement an overall efficiency of 72 per cent for the complete rectifying system may readily be obtained. For a 50-kW station the saving in the cost of power due to the use of machines is thus only £350 per annum. It is also necessary to take account of the fact that the use of a high-tension machine renders the station entirely dependent on one large unit of very special design which, in case of breakdown, can only be replaced after considerable delay. It is therefore practically essential where such machines are used that they shall be installed in duplicate, if continuity of service is to be maintained. I have worked out roughly the capital costs of a duplicate set of high-tension machines and of a rectifier system with duplicate high-tension transformer, and I find that for a 50-kW station the difference is equivalent to an annual charge of £1 000 against the former. Setting against this the £350 saved by the machine on account of its higher efficiency and also the £1 500 which represents the cost of valves for the rectifier, the net result is that the rectifier shows a deficit of £850 per annum for each dual station, a figure which is a good deal less than the £2 400 suggested in the paper. Before deciding on the use of high-tension machines it is, I think, necessary to consider very seriously whether this expenditure is not justified by the greater security obtained with a rectifier system. It is interesting to compare the frequency characteristics given in the paper for 2LO, 5GB and 5XX. These indicate clearly the improvement that has been effected in the new station and also the ill-effects of side-band cut-off in the radio-frequency tuned circuits. As an example of the extent to which the latter trouble can be overcome, it is of interest to note that for the television demonstration conducted recently by the American Telephone and Telegraph Co. it was necessary to construct a 5-kW broadcasting transmitter having a frequency characteristic which was flat from 20 to 20 000 cycles. Regarding the improvement obtained at 5XX by slightly mistuning the aerial circuit, I am wondering whether this tells the whole story and whether it was not necessary to mistune both the aerial and the closed circuits, "one up and one down," in the manner previously mentioned by the author. If only the aerial circuit is mistuned, it would appear that the given characteristic is obtained by favouring one of the side frequencies at the expense of the carrier and the other side frequency. This may give good results when the receiving set is tuned accurately to the carrier frequency or slightly mistuned in the same direction as the transmitting aerial, but in the case of a receiver which is slightly detuned in the direction of the suppressed side frequency the results will be worse than before. In any case it seems wrong in principle to transmit with side frequencies of unequal amplitude. On page 114 I note that the suggestion of employing a band-pass filter in the intermediate-frequency amplifier of a superheterodyne radio receiver is attributed to Mr. Kirke. It cannot, I think, be maintained that this idea is by any means new at the present time, although so far as I am aware it is not actually employed in any commercial superheterodyne sets. A plan which is economically much more practicable and which is aimed at to-day by the manufacturers of better-class superheterodyne sets is to design the intermediate-frequency transformers in such a way as to give them inherently a band-pass characteristic. By suitably proportioning the primary and secondary capacities, the leakage and mutual inductance, the resistance, etc., this can to a large extent be done, so that the desired result is secured without the introduction of any additional apparatus.

Mr. A. J. Gill: Speaking of mast design, the author mentions that proposals have been made to use wood, stone or concrete masts, "but," he says, "the mechanical difficulties and high costs would appear to make the suggestion impracticable." Stone would probably be impracticable, and also concrete if reinforcement had to be avoided, but I cannot see where the difficulty lies in using wood. Wooden masts have been used for years. There are some in Rome 715 ft. high, and 3 at Horsea 440 ft. high, which were put up in 1913 and are still standing. One of these was struck by an aeroplane during the war, but was successfully repaired, the broken struts being taken out and new ones put in. There would therefore appear to be no mechanical difficulty in erecting wooden masts of sufficient height for any requirements of broadcast work. On page 114 a suggestion is made for using a superheterodyne receiver having high damping on the aerial circuit in conjunction with a band filter of standardized design in the intermediate-frequency stage. One of the great difficulties in using a superheterodyne receiver is that for every adjustment of the oscillator frequency the detector and intermediate stages are receptive to two different frequencies, the oscillator plus the intermediate frequency and the oscillator minus the intermediate frequency, and to

exclude the unwanted frequency it is essential to have a high degree of selectivity prior to the first detector. The conclusions which the author has reached on the relative merits of high- and low-power modulation are of very great interest to those concerned with the design of telephone transmitters. The experience that the Post Office has had in that design is chiefly on short-wave work and we have come, so far as the question of power is concerned, to the same conclusion as the author, namely that approximately the same power is required for either type of modulation. With short waves the difficulties of amplification are apparently rather greater, and in that way high-power modulation is rather more easy to carry out. With regard to the frequency band that is, or should be, transmitted, it may be of interest if I show the curve that is required for ordinary speech telephony, and I have had a diagram prepared in which I have taken the curve B in Fig. 7 of the paper, which is the overall curve transmitted from the antenna, and put with it another curve which I have marked A,

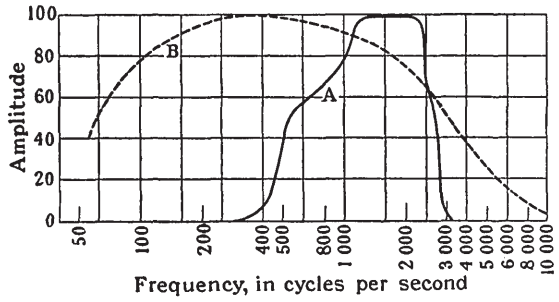

FIG. A.

Curve A: Overall curve for Rugby (GBT).
Curve B: Overall curves for Daventry (5XX).

showing the band transmitted from Rugby on the Transatlantic telephony transmitter GBT. It will be seen that the transmission does not commence until something over 300 cycles. It rises to a maximum of about 1 200, continues practically flat to somewhere about 2 700, and then drops away suddenly and disappears at 3 000 cycles. It is possible to get perfectly good speech by utilizing that band of frequencies, and I think it is of interest to show those two curves together. I have noticed another rather interesting point. I was once experimenting with a low-pass filter having a sharp cut-off at 3 000 cycles, and I took the broadcasting from 5XX and put it through this filter. That meant that everything above 3 000 cycles was cut off, but I could detect no difference.

Mr. R. W. Minter: When dealing with broadcasting controversy it is not right to let the problem of interference go unmentioned. There is an air of finality about the author's statement under the heading " Historical " in the early part of the paper, that " The long wave is not interfered with by obsolescent spark transmitting-apparatus," but 5XX seems to be interfered with by modern valve apparatus. The modern valve apparatus at the Air Ministry station breaks into the " A " area of Daventry and the " A " area of Radio Paris and carries on down to Hilversum, on whose wave-length another modern station—the Post Office station at Devizes—can be heard. It appears, therefore, that the much-maligned spark transmission is not the only source of trouble. It seems rather surprising that no actual measurements of the field round about the transmitter have been made by the B.B.C., because the Post Office has taken some very careful tests at Leafield and these have been published. There is no reason why it should not be done by the B.B.C. on the higher frequency and this might result in a certain amount of trouble, experienced in working new stations, being got rid of. Throughout the paper there are constant references to the fact that the development of the B.B.C. will follow the development of the design of broadcast receivers; this would appear to mean that if we have a bad receiver we shall immediately get a bad transmission. This is rather a strange statement. The author also mentions that the majority of listeners are more or less tied to the reception of one station. Does this refer merely to the people who have written to the B.B.C., or to all those who actually listen to the wireless programmes? Mr. Turner has touched on transmission over land lines for simultaneous broadcasting. It has been suggested that as much trouble will be experienced in getting perfect transmisssion over land lines as with any other system, and the author rather dismisses the idea of the Rugby no-carrier system of telephony as having reached its maximum, but I do not think the Post Office would agree to that, and if costs can be brought down I think that a great improvement over land-line transmission will be obtained; at any rate as far as Rugby is concerned I think the Post Office authorities will say that this is true.

Mr. F. H. Amis: The author has shown in Fig. 1 how the field strength obtained at various distances from the transmitter differs for the frequencies of 610 and 1 040 kilocycles. In studying the curves, however, it would be interesting to know whether the radiated power was the same in each case, or whether the total power put into the antenna was held constant for the two cases. On page 110 a comparison is made between a quarter-wave and a half-wave antenna. Due to the poor design of the former, the half-wave antenna is shown to advantage. The design of the two antennæ depended no doubt upon the masts available, but it is probable that the half-wave antenna would have shown much less to advantage had it been possible to compare it with a well-designed antenna of the quarter-wave type. Nothing is said about the use of multiple-tuned antennæ which give high efficiencies at a reasonable mast cost. From my experience with multiple-tuned antennæ I should say that if the comparison had been made between a well-designed quarter-wave antenna of this type and the half-wave antenna, the results would have been in favour of the multiple-tuned antenna from an economical viewpoint. Thus it would appear that the efficiency for which the author is striving could be obtained with a quarter-wave antenna of the multiple type, and the charge of £600 per annum referred to, avoided. Incidentally, the " tip " effect which is obtained when a half-wave antenna is employed and which the author regards as a disadvantage would be avoided. It is noted that the 5GB antenna is fed by a transmission line. It would be interesting to know what is the order of the voltage developed across the secondary of the transformer feeding the antenna

and also whether any difficulties have been met with in dealing with this voltage, which one would expect to be very high when dealing with a half-wave antenna. It would also be very interesting to know to what extent the increase in efficiency due to absence of the transmitter building under the antenna is counteracted by the losses in the transmission line. I was pleased to note that the idea of using the masts as, or as part of, the antenna had been raised. The idea occurred to me about two years ago, but I appreciated that it is a subject fraught with difficulties. In the first case it is necessary that a self-supporting mast be used, unless an umbrella antenna is considered. The cost and difficulty of building a self-supporting mast insulated by porcelain insulators would probably outweigh any advantages gained. Also, as the author points out, they would be apt to heat and crack, due to the high-frequency high potential across the insulators. My idea was not, however, to use such a mast for a half-wave antenna, but for a quarter-wave antenna where the potential across the insulators would be considerably less. It has occurred to me, however, that a way out of the difficulty (for a quarter-wave antenna) would be to construct the mast using fairly massive concrete foundations, but no insulators. The dimensions of the mast should be such that when connected to earth its natural wave-length is just short of the operating wave-length. Instead of earthing the mast directly, however, earth it through a tuning coil which would tune the mast to the operating wave-length. The inductance to be added would be so small that the impedance of the concrete compared with that of the coil would be very high. The extent to which the increase in efficiency due to the tuning of the masts would be counteracted by the losses in the concrete and the masts is a matter for experiment. I have always thought that the tuned-mast idea could be most suitably employed in a multiple-tuned antenna arrangement, for instance a T antenna supported by two masts. The wires forming the top of the T would be connected electrically as well as mechanically to the masts. The transmitter would feed the centre down-lead, and the masts (forming the outer down-leads) would be so tuned that the currents in each mast and the centre down-lead were equal.

Mr. R. A. Watson Watt: Users of cathode-ray oscillographs must hope that the author will give further information as to the experimental origin of the two lines in Fig. 11, the units of the abscissæ, and a statement as to whether K is a single constant or whether it is, as certainly seems necessary, different for the two curves. They would also like to learn more about the frequency term in the sensitivity of the oscillograph, and its dependence on the operating conditions of the ionic beam. It seems very desirable that we should know whether and when, in addition to our existing difficulties with the oscillograph—in that it has a resistance of only a couple of megohms, and an impedance of about 20 000 ohms at the frequencies with which the author is concerned—we must be prepared to meet this rather curious threshold effect, which I infer from the curves to involve not a mere fraction of a volt but something between 8 and 12 volts. It would be of interest if the author would throw some light on this phenomenon in his reply to the discussion.

Mr. E. B. Moullin: I want to support the author in his view that a broadcast receiver should be regarded purely as a domestic appliance for producing music and the like, and should not require expert handling or be made so as to be a temptation for expert mishandling. In providing very copious field strengths over very large areas I feel that the B.B.C. are generously assisting the public to provide themselves with receivers which require no adjustment whatever and can be operated, with change of programme, by a simple 3-way switch. So long as the desire remains to reach out promiscuously into space and to reinforce faint sounds into audible music, so long, I think, will large numbers of users receive distorted music and much excellent transmission be partially wasted. The author's definition of "A" and "B" service areas is extremely interesting; on referring to Fig. 7 of Mr. Barfield's paper it will be noticed that the "B" service area for 2LO extends only to St. Albans, Windsor and Reigate. The field strength at Cambridge is only about 0·75 mV per metre, and in view of the present definition of "B" service area it is now plain why some five years ago it seemed difficult to obtain there a regular broadcast service without perpetual receiver adjustment. On page 109 the author states that "The fading characteristic of a station is influenced by a large number of factors, especially transmitting aerial design." I should be very glad if he would tell us more about the relation between transmitting aerial and fading. Fig. 1 appears to me very striking, for at a given distance the field strength seems to be exactly proportional to the wave-length instead of in inverse proportion as might have been expected. I should like to know whether the author has any values for intermediate wave-lengths, whether this proportionality still holds good and whether the same is true of 5XX. On page 112 the author says that one of the disadvantages of using frequencies around 200 kilocycles for broadcasting is "difficulty of reception in urban areas." I am not clear what is the connection between urban disturbance and a frequency of 200 kilocycles.

Mr. E. W. Braendle: The idea of using two stations on the same wave-length and transmitting the same programme may be reasonable, but it seems rather optimistic to expect that two programmes can be transmitted as the author appears to suggest, because then the side-band distortion due to the two programmes will come in. When transmitting the same programme might it not be possible for similar phase-changes to take place not only in the high-frequency transmission but also in the low-frequency modulation, which again would cause side-band distortion? Even though both the master control and the modulation control be situated midway between the two stations, the two lines and their attendant amplifiers, etc., might be balanced accurately enough for the master frequency, but the hope of attaining equal attenuation for all the modulation frequencies may theoretically be possible. Judging, however, from the effect of land lines on many transmissions the idea is not altogether practical, and, combined with the possible unequal note distortion, might even result in some notes being sufficiently "out" to produce a beat frequency of their own.

Mr. W. L. McPherson: It is interesting to find the

author adding his voice to the general plea of communication engineers to consider communications not on a national but on a European basis. On page 112 he makes the broad statement that in order to avoid heterodyne interference a separation of not less than 3 000 miles must be considered. That is a separation of continental dimensions, to say the least. Among the requirements put forward by the author is that of deep modulation, and I should like to know the basis of that requirement. A previous speaker has mentioned that at the receiving end we generally have detectors which are subject to distortion on deep modulation. On the other hand, at the transmitting end we have to consider an input which has a form factor very much larger than is generally appreciated. Speaking from memory, I believe that for ordinary speech the peak is about 7 times the R.M.S. value. In that case a full 100 per cent modulation could be used and yet the R.M.S. modulation would not be more than 14 per cent, and I do not think the detector distortion would be noticeable. It would be interesting if the author could give some figures as to percentage modulation actually measured at a station during programmes on both speech and music. On page 124, reference is made to the possibility of driving the transmitting set through a valve step-up arrangement so as to avoid the possibility of coupling back from the aerial system to the oscillator. This is followed by the statement that it is only fully applicable to high-power choke-modulation systems. I am not quite sure why that should be so. The Rugby system, which is the largest of its kind, involves a frequency step-up, and is certainly not a high-power choke-coupled system. Referring to the question of the cathode-ray oscillograph, in Fig. 10(*b*) the error is attributed to the threshold effect. I do not see how that arises. The threshold effect would start at the tip of the true figure, this being prolonged in a straight line, and we have actually observed this effect—that is, a triangle followed by a straight line—along the horizontal audio axis. At the same time we have also seen on occasion an inverted triangle, generally when the audio voltage on the oscillograph was out of phase with the modulation, and the boundaries of the figure were consequently ellipses (instead of straight lines) and not well defined. Possibly Fig 10(*b*) really refers to such a case.

Mr. M. G. Scroggie: Referring to conclusion (5) on page 114 under the heading "The Provision of Alternative Programmes," I have recently been making some measurements on aerial circuit selectivity and the results appear to indicate that the largest aerial may be employed to advantage even in the proximity of a powerful interfering station. The aerial is tapped down the aerial tuning inductance until the desired selectivity is attained. By increasing the size of aerial the tapping must necessarily be brought lower down, i.e. nearer to the earthed point, in order to cut out the interference, but the result on the wanted signal is an increase in strength. This advantage is not so great in cases where interference is very intense or where the remaining circuits of the receiver are non-selective, but there do not appear to be any circumstances in which a reduction in the size of aerial is to be preferred to an alteration in tap position, and the latter is the more convenient adjustment. The only argument I can see against this method is that, as pointed out in conclusion (3) on the same page, even with aerial circuits without any form of reaction one can get quite serious side-band cut-off by reducing the resistance to a sufficient extent, as shown in Fig. 3. I have made measurements somewhat similar to these which agree substantially with what the author has found. On 400 metres with an aerial of approximately 15 ohms resistance, tapping down on the aerial tuning inductance to the point where the greatest strength of wanted signal is obtained, the 10-kilocycle side frequencies are reduced to 60 per cent of full strength. Where interference is severe the tapping would have to be lower still, with consequent larger cut-off; but unless one is willing to introduce more tuned circuits that cannot be avoided. On page 110 a comparison is made between the cost of stations with high masts and low power and low masts and high power. It is true that the author states that the cost of the low mast is neglected, but the extra capital charge on the plant necessitated by the increased power of the transmitter also appears to be neglected. It is not quite clear why there should be difficulty in the reception of a long-wave station in urban areas, as mentioned on page 112. Fig. 17 indicates that a 10 000-volt d.c. machine is used, as mentioned in the paper, but also shows a 6-phase rectified a.c. equipment, which appears to be in parallel with the d.c. generator. Is that a stand-by arrangement?

Dr. R. L. Smith-Rose: I am rather interested in the mast question which is raised in the paper. The problem of whether a mast supporting an aerial system should be of wood or of steel and, if the latter, whether insulated or not, is one which has been much debated by wireless engineers for many years, and I believe that until these experiments were carried out at Daventry no satisfactory results were obtained which showed that it mattered either way. The Rugby station was built with metal masts insulated from the ground, but arrangements were provided for earthing the masts. The real point at issue depends upon the relation of the natural frequency of the mast to the frequency corresponding to the wave-length being employed. In a normal wireless station, using wave-lengths of from a few hundred metres upwards, the natural wave-length is much lower than the wave-length being employed, but in the case of stations using half-wavelength aerials the position is rather different. When the earthed metal mast has a wave-length well below the wave-length which is being transmitted, I think the sole effect of the mast is to screen the radiation, but that screening effect is very small for a single mast and to stop the radiation entirely it is necessary to surround the aerial by a whole ring of masts. The case is analogous to that of the receiving aerial, with which it is frequently more convenient to experiment. The difficulties which occur at Daventry are, I believe, two-fold. First of all the radiation from 5GB is screened by the high masts belonging to 5XX, and also the polar diagram of 5GB is distorted by the effect of its own masts, the natural wave-length of which approximates to that of the radiation. In the latter case the re-radiation from the two masts may con-

tribute to an important extent to the total emission. The shape of the polar diagram of the radiation field from the whole system will depend upon the actual dimensions of the aerial masts and of the spacing of the latter. With two masts supporting an aerial midway between them the polar diagram of the field due to the masts would tend to conform to a figure-of-eight arrangement, and one might suggest that this could be smoothed out to some extent by using four or a greater number of masts arranged symmetrically about the aerial. Technical solutions of the problem are not lacking, however, and it is rather a question of economics. Referring to another point in the paper, I am inclined to doubt whether the rating of a transmitting station by the power supplied to the aerial is the most satisfactory manner of describing the station. I think it is better than describing the power supplied to the transmitter or even to the oscillator valves, but I am not sure that it gives an effective comparison of radiation from the station, because a great deal of power might be supplied to the aerial, with only a small radiation. The power supplied to the aerial is limited by the total resistance of the aerial, whereas the radiation obtained from it depends entirely on the radiation resistance. In spite of the author's footnote on page 108, I would suggest that the quantity "metre-amperes" does express the radiation from the aerial in a more satisfactory manner, even when allowance is made for the limitations of our knowledge of effective heights.

Captain P. P. Eckersley (*in reply*): Mr. Turner, among others, has misunderstood a remark in the paper which is perhaps liable to misinterpretation. On the question of dislocation it has been said that "It is important to study the problem [of changing the sites of and powers of stations] in terms of existing reception technique." Mr. Minter has interpreted this as meaning that "if we have a bad receiver we shall immediately get a bad transmission." I can only point out to Mr. Minter that, whatever receiver he has been in the habit of using, our transmissions themselves are, both from measurement and from experience, as good as any in the world and that my remark had nothing to do with the quality of transmission. The point to be made is, however, that if a large body of listeners has been living within a wipe-out area there will be considerable outcry and substantial loss of revenue if conditions are changed to bring such listeners within a "B" service area. Scientifically, reception conditions in a "B" service area are satisfactory, but the abrupt change from, say, 100 to 10 millivolts per metre brings a sudden dislocation resulting in complaint and embarrassment of a political nature. My remark applied, therefore, only to the dislocation brought about by sudden changes in field strength. It had no reference to the actual obsolescence of the type of set used by listeners.

Mr. Turner implies, from the statement, that we are apt to spoon-feed the listener in the matter of field strength, but experience shows that on its lowest terms this produces greater licence revenue; on its highest terms it makes broadcast reception possible for the very poorest populations, and on a scientific basis overcomes interference. It is a fact that in densely populated areas it is impossible to guarantee freedom from interruption unless the field strength is between 10 and 20 millivolts per metre. With scattered points of dense population the theoretical solution is many small-power stations, but owing to the insufficiency of channels or wave-lengths the only practical solution is to use the highest possible power with comparatively few stations. Mr. Minter supports this view, saying that he has noticed interference in "A" service areas, and therefore he must have measured the field strengths of the stations he mentions. We have not, however, noticed interference from the Air Ministry station within the "A" service area of Daventry.

On the question of our expressed ideal to get an equal representation of all frequencies between 50 and 10 000, Mr. Turner points out that the frequencies below 50 are important. This is agreed, but if on a practical issue there can be 100 per cent modulation at 50 cycles the other frequencies will be present in sufficient ratio. Mr. Gill describes an experiment in which he eliminated all frequencies above 3 000 and below 300 but found no difference whether they were present or not. This can probably be explained by realizing that in any case the reproducer itself (telephone or loud-speaker), if of conventional design, itself eliminates these frequencies.

Mr. Turner speaks of the use of land lines for interconnecting stations, and doubts whether this is really a system that can be fully recommended, in view of its failure on certain occasions. In the paper it is stated that "provided proper precautions were taken" this is the best method of interlinking stations. In my opinion, failures are not intrinsically due to the system as such but rather to the inherent difficulty of using overhead lines in stormy weather. Future schemes rely entirely upon the use of buried cable, which does not suffer from unreliability in the same way. There is no technical ban to ultimate perfection in interconnecting stations by land line; unreliability is to-day the only difficulty.

Mr. Turner's final remarks as to detectors lead me to say on the one hand that the problem is one to be solved by receiver designers rather than by forcing transmitters to be more than ever extravagant in power by having to modulate feebly, and upon the other hand to point out that under usual studio conditions the R.M.S. modulation is never more than 15 to 20 per cent.

It is difficult to accept Mr. Mason's suggestion that the highly inductive choke inherent to the smoothing system acts to check flash-over in valves in the same way as a choke directly in series with the anode supply. In the former case large condensers shunt the end of the choke to earth, whereas in the latter case no such condensers exist. Mr. Mason, however, argues that these condensers cannot store enough energy to produce flash-over. While I agree that this is true, they can supply momentarily enough energy to maintain and augment an arc started in whatsoever way, whereas the plain choke directly in series with the anode supply will act momentarily to quench the arc.

Since writing the paper a valve rectifier limiter has been installed at 5GB in series with the direct-current supply. Flash-over conditions still take place but do less damage. They are, however, far more apparent,

causing noises on transmission and sometimes some damage to circuit components, than with 5XX (high-power modulation) where the voltage used is 11 500 and the make of valves the same, although slightly lower in rating. It is not proved, but it would nevertheless appear from the above, that a low-power modulation system where the highly inductive series choke is eliminated is more subject to flash-over effects, given the same type of supply for each system. The too numerous breakdowns at 5GB—a wholly experimental station providing an alternative service—have been almost wholly due to valve flash-over. It is believed that both anode supply from direct-current machines and low-power modulation systems present such manifold advantages that to abandon them for fear of valve flash-over is wrong; rather is it better to concentrate on the problem of eliminating flash-over in the valve and in the meanwhile apply such palliatives as may seem efficacious until the valve is produced which does not exhibit instabilities.

Mr. Mason does not appear convinced that direct-current supply represents a substantial economy, and he challenges the figures given in the paper. The figure of 60 per cent for the overall efficiency of a rectifying system was measured directly from a practical case. This involved a 2-wave rectifier with double-anode water-cooled valve and an applied single-phase alternating current of a frequency of 300 cycles. Mr. Mason's 3-phase arrangement gave 72 per cent, but this probably involved a more expensive valve equipment (all to be replaced after a given time). Taking Mr. Mason's figures, however, the saving for a 50-kW station is, as he states, £350 per annum. For 10 stations (or 5 twin-wave stations) this is £3 500. The cost of maintenance of rectifiers for a twin-wave station is £1 500 per annum, or £7 500 for 5 stations. This is for a single-phase rectifier; might not the figure be higher for 3-phase working? The capital cost write-off (on a 10 years' basis) for the d.c. high-tension machinery for 5 twin-wave stations is, on actual quoted figures, £5 000 per annum. (It must be appreciated that a twin-transmitter station can be equipped with 3 machines for 2 transmitters, one between the two remaining as spare. Possibly Mr. Mason did not appreciate this point.) It must be remembered that the a.c. plant and rectifiers must be similarly written off. On the same basis I make this £3 000 per annum. Thus the *saving* due to using d.c. machines for 5 twin-wave stations is (on Mr. Mason's efficiency figures of 72 per cent for the rectifier) £3 500 per annum in power and £7 500 per annum for rectifiers (conservative), making £11 000 per annum in all. Subtracting £2 000 as extra write-off for d.c. machines and adding to this, say, £1 000 per annum for repairs, we get (on Mr. Mason's figures) a total saving of £9 000 per annum. Thus I think Mr. Mason's figures (although by accepting 72 per cent as the efficiency of a rectifier this greatly changes the figures given in the paper) should be modified to those given above, which still show a substantial gain in favour of direct current. As to security, the use of direct current presents no exceptional risk in view of the facts mentioned in the paper as to reliability, and further because wireless stations have been driven from high-power d.c. machines without breakdown for the last 6 or 7 years.

The improvement of frequency characteristic at 5XX was certainly effected by mistuning both circuits, one up, one down, otherwise the difficulties which Mr. Mason hypothesizes might have been met with in practice.

The suggestion as to the use of the superheterodyne receiver embodying a band-pass filter in the intermediate-frequency stage was first made to me by Mr. Kirke; possibly it has been made before, but apparently there has, as yet, been no practical outcome. It would be interesting to see the frequency characteristics of the receivers which, in their transformers in the intermediate stage, attempt to achieve the basic performance asked for. From listening, I feel that many of them achieve cut-off most successfully but never—as far as can be judged by ear—abruptly at high frequencies. Mr. Gill is right when he points out that there are two places of tune, and this may introduce jamming, but for broadcasting in the proper sense it is assumed that the receiver would be used only where the transmission to be heard is very strong and overpowers the 10-kilocycle-separated neighbour.

Mr. Gill favours the use of wooden masts. Certainly these would overcome all shielding troubles, but it is feared that the structures might become unsafe long before those made with steel, and there is, it is felt, a good deal of danger from fire. It is believed that certain wooden masts supporting wireless antennæ have actually caught fire in practice.

Mr. Amis's discussion of the papers deals with aerial design. The radiated power, in comparing the field strength at different distances using 1 040 and 600 kilocycles carrier-wave frequency, was *not* the same, but the power input to the main high-frequency magnifiers was identical. This is tantamount to saying that the aerial power was the same and thus the radiated power was dependent upon the radiation efficiency of the aerial. This is probably as good a practical comparison as any, but it has been stressed that the paper has by force of circumstances confined itself largely to qualitative statement. The British Broadcasting Corporation is at present engaged, as it has been for several months, on a quantitative study of all factors connected with aerial design and frequency of carrier wave used, and it is hoped that the results, when complete, will be published. This answers Mr. Minter's question. Mr. Moullin's question is dealt with by the further explanation given above.

Dr. Smith-Rose raises some interesting points in connection with masts. The masts used at 5GB during the initial experiments were of the 110-ft. steel-tube type resting on concrete foundations. It was found that an extremely asymmetrical polar diagram resulted, the nearby 500-ft. uninsulated steel masts used for the 5XX aerial producing a severe shielding effect. New masts 300 ft. high, uninsulated and resting on concrete foundations, were erected but $\frac{1}{4}$ wave-length further away from the large 5XX masts. The polar diagram was in these circumstances vastly better. This indicates that it is important to remove aerials as far from one another as possible, owing to direct shielding and phase distortion of disturbances set up in local

structures. Incidentally the 300-ft. masts now used for 5GB have a natural wave-length not far different from that used by the station, and yet the masts do not appear to affect the polar diagram. This may be purely fortunate, it being impossible to work out the case as it contains so many variables. The wisest plan would appear to be to insulate the masts (they can then if necessary be earthed or tuned) and remove them as far away from the aerials as possible.

Regarding the comparison between half-wave and quarter-wave antennæ, Mr. Amis suggests that the quarter-wave type could be improved by using multiple tuning. This is probably true, but equivalently the half-wave type could be proportionally improved also; comparison must surely be made under similar conditions. Multiple tuning has been used on the London station, but in this case at any rate it introduced directional effects.

The transmission line at 5GB shows by measurement that losses are negligible. The same applies to the London station aerial also, which is fed by a feeder. The R.M.S. voltage developed across the secondary of the coupling transformer between feeder and aerial at 5GB is 3 500 volts. No trouble has been experienced with this quite normal voltage. The suggestion that a mast could be used as an aerial but that the concrete foundation might serve as the insulator is not entirely new. If the voltage across the concrete to earth were high, large losses would accrue, but Mr. Amis suggests that by suitable arrangements, the loading inductance to the mast being small, such losses might be negligible. This is possibly true and deserves fuller investigation. Without measurement it is impossible to be dogmatic. I feel, however, that losses might be more than could be justly allowed, the power being a major item in the cost of running a broadcasting station.

Both Mr. Watson Watt and Mr. McPherson have asked for further enlightenment on the behaviour of the cathode-ray oscillograph. Firstly, the constant given in the paper is not a single constant; secondly, the focus required (for clear definition) is not the same for a large as for a small deflection. If the focus is arranged for a medium or large deflection and clear definition it is probable that the spot at zero applied plate voltage will be large, the beam tapering at some point between anode and fluorescent screen but expanding again on the screen. A certain applied threshold voltage will then cause the taper to change and the spot will become small. This effect only occurs when the filament is bright enough to give clear definition for big deflections, but is therefore always present. The two curves in the paper were taken at different filament temperatures. The threshold effect is thus always present when proper definition is required for the purposes explained in the paper.

The reception of 5XX (frequency 200 kilocycles) is always better in rural than in urban areas. This is due to two causes, firstly the larger aerials that can be used in the former case and secondly the severe dielectric losses in the latter case. Mr. Moullin's question on this point is thus answered.

Mr. Braendle rightly points out that if it were possible to hold the carrier waves of two stations at the same frequency and the same phase relationship there would still be the question of side-band interference to consider. The high-frequency interference would take the form of different cancellations or additions of different side-band frequencies at the same point in the field set up by the action of the two stations (frequency characteristic distortion), and also different cancellations or additions of side bands compared with the carrier-wave cancellations and additions. The low-frequency out-of-phase effects introduced by the effect of two different lines carrying the modulations from one studio to two transmitters would produce some distortion but, judging by experience of mixing at low frequencies for echo purposes, nothing so serious as the high-frequency effects. It is fair to assume, however, that at some point relatively near one station the effect of the other would be negligible. Thus although there would be an area of bad quality between two stations operating on the same carrier frequency, the wipe-out "A" or perhaps "B" service area might remain, given proper geographical separation, intact and undisturbed. A point to consider is that the beating together at whatever audible frequency of carrier waves constitutes a 100 per cent modulation effect in receivers; the beating together of side bands represents practically a less effect, allowing the service area to be extended when single-wave working is in operation. Thus areas of bad quality might be filled by a third station and the whole of a programme could be transmitted over as large an area as desired through two channels using two groups of stations, each group sharing two different waves only.

Mr. Scroggie appears to have confirmed some of the results concerning receiver selectivity and side-band cut-off given in the paper. He asks whether the paralleling of d.c. and a.c. supply plant at 5GB is in order to use the a.c. supply as stand-by. Eventually this will be so used, but at present both supplies are used in parallel.